§13. Burning Criteria for D-^{3}He Reactor

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Burning criteria for a D-^{3}He fusion reactor have been investigated by using the 0-D power and particle balance equations and the IPB98(y,2) scaling law [1]. In order to simplify the problem, ST configuration with ITB and the bootstrap current fraction of 100 % are assumed.

The model is as follows: Equations to be solved in this paper are the energy balance equation, as

$$\frac{dW}{dt} = P_{heat} - \frac{W}{\tau_E}$$

and the particle balance equations, as

$$\frac{dN_k}{dt} = v_k - \frac{N_k}{\tau_p} - \frac{1}{V}\sum_i S_{jk} + \frac{1}{V}\sum_{i+j\to k} S_{ij}$$

where W(t) is the internal plasma energy, N_k and v_k is the total particle number and the external particle supply of nucleus k, respectively. The summation indicated by i+j →k is the whole fusion reaction creating a nucleus k, (i, j, k=H, T, D, ^{3}He, C). The electron density n_e and the ion density n_j satisfy the charge neutrality. The energy confinement time τ_E is assumed to be γ_{HH} times of the IPB98(y,2) scaling. Spatial profiles of the temperature and density are assumed to be an ITB model as $T_j(r) = T_{j0}\, g(x; b_T, m_T)$ and $n_j(r) = n_{j0}\, g(x; b_n, m_n)$. Here x=r/a, and

$$g(x;b,m) = \begin{cases} 1 - \dfrac{x^{2m}}{b^{2(m-1)}} & (0 \le x \le b) \\ \dfrac{(1-x^2)^m}{(1-b^2)^{m-1}} & (b \le x \le 1) \end{cases}$$

Figure 1 shows the T_i/T_e and the fraction of neutron power in the total fusion power versus the ^{3}He in the case of R=6 m. When T_i=T_e, n_D: n_{3He} =2:1 and the neutron fraction is 10 %, which is 1/8 of the D-T reactor. When n_{3He} =60 %, the neutron fraction is 1.9 % of the total fusion power, which is less than 1/40 of the D-T fusion. The T_i/T_e should be greater than 2 in order to operate the reactor with n_{3He}=60 % even if no impurity other than fusion ashes (H and ^{4}He) exists in plasma. D-D reactor or a low-neutron D-^{3}He reactor require the condition T_i/T_e > 2 even if no impurity other than the ^{4}He ash remains.

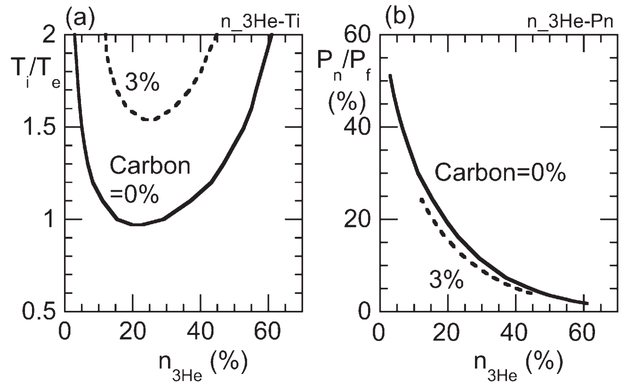

Fig. 1 (a) Temperature ratio (T_i/T_e) and (b) fraction of neutron power in total fusion power versus ^{3}He contamination in the steady burning state.

Figure 2(a) shows the minimum toroidal field (B_t) to obtain a particular central beta (β_0). Fig.2 (b) shows the averaged beta (<β>) versus normalized radius of ITB foot point (b_{ITB}) in the case of, B_{coil}=20 T (B_t=3.63 T) and β_0=1. Other conditions (R=6 m, T_i/T_e =1.6, n_D: n_{3He} =2:1 and n_C=3 %) are common in both figures.

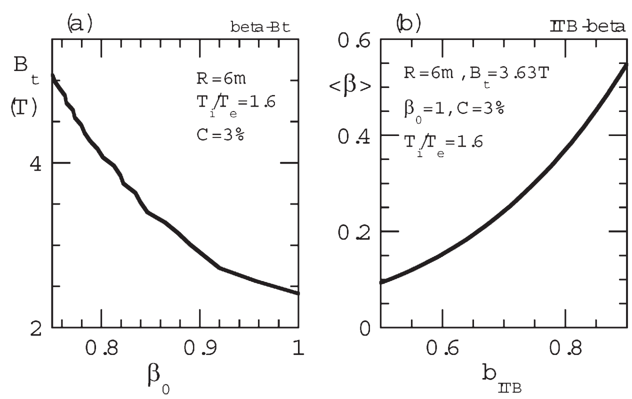

Fig. 2 (a) Required B_t to obtain β_0 in the case of b_{ITB} =0.85. (b) Averaged beta (<β>) versus b_{ITB}.

The result shows that when <β>=10 %, D-^{3}He reactor is possible if β_0 is about unity and T_i/T_e>2. This is applicable to helical reactors.

[1] Y. Nagayama, Y. Tomita, IEEJ Trans. FM, Vol.125, 947 (2005)